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SUMMARY OF PROCEEDINGS OF THE CONFERANCE ON LOW POLLUTION POWER SYSTEMS DEVELOPMENT HELD AT EINDHOVEN (NETHERLANDS) 23-25 FEBRUARY 1971

NATO Committee on the Challenges of Modern Society

25 February 1971

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SUMMARY OF PROCEEDINGS

OF THE

CONFERENCE ON LOW POLLUTION

POWER SYSTEMS DEVELOPMENT

NATO Committee on the Challenges of
Modern Society

Eindhoven, The Netherlands
February 23, 24, 25, 1971

Air Pollution Control Office
Environmental Protection Agency
Rockville, Maryland

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An Overview of the NATO/CCMS Conference on Low Pollution Power Systems Development

The NATO/CCMS Conference on Low Pollution Power Systems Development was held in Eindhoven, Netherlands, on February 23-25, 1971. The Government of the Netherlands and the Philips Company co-hosted the Conference. The arrangements and hospitality were truly superb, and the United States, as the pilot country on air pollution, expresses its sincere gratitude for their assistance in making the Conference a success.

The total attendance for the meeting was just under one hundred government and industry representatives from twelve countries, as well as non-NATO international organizations. The following countries were represented: the Netherlands, Belgium, Canada, Denmark, France, Germany, Great Britain, Italy, Turkey, Sweden, Japan and the United States. The Organization for Economic Cooperation and Development (OECD) and the European Economic Community had observers in attendance.

The Conference was divided into two sessions with the first day being reserved for government representative presentations and discussions regarding country programs and policies relative to the automobile pollution problem. The second and third days were devoted to technical presentations on research and development projects by both government and industry attendees.

In his welcoming address His Excellence H. J. de Koster, State Secretary, Foreign Ministry of the Netherlands, set the tone of the meeting on a high note of concern regarding the need for close cooperation in this field (Appendix A).

During the course of the first day's activities, four papers were presented by the United States, three by the Netherlands and one each by France, Japan, Great Britain and Italy. These papers dealt primarily with governmental programs and policies regarding motor vehicle pollution control. After a repeat of the U. S. papers given on the previous day, the second and third days produced twelve technical papers from seven countries on technological developments of turbine, hybrid, steam, Stirling and electric power systems.*

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*A technical document which includes the presentations given at the Conference is available from the Air Pollution Control Office of the Environmental Protection Agency.

The chairman solicited the cooperative efforts among the countries in attendance to engender a strong multi-lateral program in this very important environmental problem area. The delegations representing the Netherlands, France, the Federal Republic of Germany, Great Britain and Japan exhibited interest either in the overall aspects of the program or in specific research and development areas.

At the conclusion of the formal proceedings, a press conference was held to discuss the activities of the Conference and to answer questions generated by the news media during the Conference. The Philips Company hosted a tour of their research facility so that the Conference attendees could get a first hand view of their Stirling engine development work.

The Conference acted as the initial catalytic forum which brought together the thinking of both government and industry representatives who are responsible for the future needs in our drive toward a better environment, both from a policy and technical point of view. The Conference Chairman, Dr. John H. Ludwig, succinctly stated the outcome and future goals of this NATO/CCMS endeavor in his concluding statement (Appendix B).

Summary of Proceedings of the Conference on Low Pollution Power Systems Development

Morning Session, February 23 (Government representatives)

1. The welcoming address was given by Mr. P. J. Hagendoorn, Director, Special Affairs, N. V. Philips. Mr. Hagendoorn then introduced Mr. H. J. de Koster, State Secretary, Foreign Ministry, the Netherlands.

2. In his remarks, Mr. de Koster emphasized that the Netherlands is the most densely populated country in the world and that the resulting local pollution of the atmosphere by motor vehicle exhaust gases has become a major problem which must be addressed. He stressed that technical cooperation on a broad basis is essential, if international trade in motor vehicles is to continue without interruption. Employing nautical terminology, Mr. de Koster stated that, "we shall need a highly skilled pilot to steer a safe course between the Scylla of air pollution and the Charybdis of potential obstacles to trade."

3. Opening remarks on behalf of NATO's Committee on the Challenges of Modern Society (CCMS) were addressed to the group by the Chairman of the Conference, Dr. John H. Ludwig, Assistant Commissioner for Science and Technology, United States Environmental Protection Agency, Air Pollution Control Office (EPA/APCO). Dr. Ludwig subsequently presented an overview of the full scope of the CCMS Air Pollution Program including a description of the U. S. Pilot Study currently being carried out in collaboration with the Governments of Turkey and the Federal Republic of Germany. Also outlined were the developments which led to the present Conference on Low Pollution Power Systems Development.

4. The purpose of the Conference was discussed by Dr. Kay H. Jones, Director, CCMS Air Pollution Study, EPA/APCO. Dr. Jones noted that under the auspices of the CCMS, the U. S. is inviting NATO member and non-member countries to participate in its program for the development of a low pollution motor vehicle either through research and development on inherently low pollution power systems or by demonstration of new concepts for controlling emissions from the conventional gasoline spark-ignition engine. Based on our knowledge of the innovative techniques employed on motor vehicle imports from abroad, together with the formidable technical resources of the non-U. S. automotive manufacturing industries, international cooperative programs could lead to accelerated progress in the development of both advanced power systems and control technology for conventional engines. Although assessment of the long-term impact of motor vehicle emissions on urban regions of the NATO community and the need for their control may not become critical for several years, experience in the U. S. indicates that it would not be premature to begin such programs now due to the long time-frame required for implementation.

5. Description of U. S. Government Programs:

A. A presentation on the rationale for stringent automotive emission standards in the U. S. was made by Dr. Ronald Engel, Assistant Director, Bureau of Criteria and Standards, EPA/APCO. Dr. Engel described elements of the roll-back technique employed in the calculation of automobile emissions standards necessary to obtain desired ambient air quality levels.

B. Mr. John J. Brogan, Director of the Division of Motor Vehicle Research and Development, EPA/APCO, traced the origin, formulation and rationale of the recently inaugurated Advanced Automotive Power Systems Program (AAPSP) which is intended to provide alternatives to the conventional engine for meeting the new Federal legislative emission standards. There are, at present, sixteen research and development contracts underway covering the various candidates. They range in scope from the design of gas turbines capable of being produced at the lowest manufacturing cost to the conduct of applied research on means to reduce emissions from gas turbine and Rankine cycle combustors. Component hardware development is an integral part of the AAPSP. On-going projects include the design of mechanical components for the heat engine/electric hybrid and the development of improved lead acid batteries compatible with hybrid system operation; also the design, construction and testing of flywheels for the heat engine/flywheel hybrid. Research and development on a lithium-sulphur battery is also being supported as part of an intensive program to provide a suitable power source for the all-electric automobile. This battery system is the prime candidate to supply the energy and power required by such a vehicle.

In view of the Congressional 1975-1976 deadline for meeting statutory emissions standards, the AAPSP has recently been restructured. A considerably increased research effort will now be devoted to solving the technical problems presently associated with the gas turbine. It is believed that achievement of practical solutions will stimulate the industry to apply this technology to its own designs. Development of the heat engine/electric hybrid system is being planned and fleet testing considered as a practical means of demonstrating technological feasibility. In addition, the stratified charge engine and the Diesel engine are being added to the list of candidates offering the potential for meeting 1975-1976 U. S. emissions standards.

Afternoon Session

1. Description of other Government programs by Government representatives:

A. Dr. J. Spaander, Director-General of National Institute for Public Health, Bilthoven, the Netherlands, listed industry, domestic

heating, motor vehicles and comparable stationary sources as the principal elements of air pollution in the Netherlands. Dr. Spaander mentioned that a nationally integrated automatic air monitoring system is now under construction throughout the country. He also emphasized that environmental regulations in the Netherlands can not be effective, isolated from what happens elsewhere in the world. The Government of the Netherlands would therefore support effective international collaboration designed to achieve control of the environment.

B. After pointing out the concern existing in the Netherlands related to motor vehicle air pollution, Dr. F. Hartogensis, Public Health Officer, Inspection for Environmental Hygiene, described the ECE emissions standards adopted by the six countries of the European Communities. In addition to control of emissions from used cars, restriction of the lead content in the fuel is presently being discussed. Dr. Hartogensis stated his conviction that a change in emphasis from private to public transport could be one of the most efficient methods of reducing total air pollution arising from motorized transport.

C. Dr. J. G. Kuiperbak, Deputy Director, Netherlands Road Transport Service, Ministry of Transport, discussed emissions controls for both new and used cars and suggested that the ultimate solution would be one world-wide set of standards. Dr. Hartogensis also expressed his opinion that new and different low emissions power systems for vehicles should be developed. Among these are included gas turbines, electrochemical cells, steam engines and hybrid combinations of these power sources.

D. Mr. Frybourg, Director, Institut de Recherche des Transports, Arcueil, France, described a program in which advances of 50 per cent of a company's R&D costs are made by the government to stimulate applied technology related to batteries and electric cars. These funds are subsequently recovered if the project culminates in a successful product. Mr. Frybourg noted that a High Commission for the Environment and a new Ministry for the Protection of Nature and the Environment (similar to the U. S. Environmental Protection Agency) have recently been established in France.

In addition to development of small electric vehicles for urban areas, catalysis research applicable to the conventional engine is being pursued. Mr. Frybourg also remarked that hybrid systems should be investigated in depth and that gas turbines are being considered as power sources for private aircraft, trains, and helicopters.

E. Mr. Suzuki, Ministry of International Trade and Industry, Japan, stated that the Government intends to regulate automobile exhaust emissions by 1975. The emissions standards projected for that year

correspond approximately to those already adopted by the U. S. Efforts are being made to improve the emissions performance of the conventional engine and to develop new catalysts. This work is being done at National Laboratories, The Japan Automobile Research Institute, and by automobile manufacturers. Research and development is also being performed on low pollution vehicle power plants which include electric cars, rotary engines and gas turbines.

F. Commander Tyrell, Department of Trade and Industry, U. K., discussed the development of electric vehicles and new electric power sources in the U. K. Government financed proposals include applied research on zinc-air batteries and construction of experimental electric buses powered by lead-acid batteries intended for use within city centers. Over 40,000 electric vehicles were registered in the U. K. during 1970. These are employed predominantly for urban delivery purposes. In regard to electric cars, the total number registered probably does not exceed 40. Enfield Automotive, however, is developing a series of small electric vehicles which they hope shortly to put into production. Fuel cell and advanced battery research in the U. K. is presently being supported by the National Research Development Corporation.

G. Some brief remarks were made by Ing. G. Rossini, Italy, related to regulation of emissions from Diesel engines and the development of catalytic afterburners for this purpose. He called attention to the fact that this was a mixed activity involving participation by both the State and industry. Thermal reactors are also being studied as an alternative method for exhaust gas treatment.

Morning Session, February 24 (Government and Industry)

1. Welcome address by Dr. John H. Ludwig, Conference Chairman, EPA/APCO.

2. Repeat of Tuesday morning's U. S. presentations.

Afternoon Session

1. Mr. E. S. Wright, Chief, Ground Systems Analysis, United Aircraft Laboratories (UARL), East Hartford, Connecticut, U. S., presented a paper entitled, "The Gas Turbine Automobile as a Low-Emissions Alternative." In his paper Mr. Wright referred to an APCO-sponsored UARL study on the manufacturing costs associated with gas turbines for automobiles. The objectives were to evaluate the feasibility of manufacturing automobile gas turbines at costs competitive with the conventional engine and to identify those manufacturing areas which require additional research. UARL designs for an advanced automotive gas turbine specify a 10-12:1 single-stage centrifugal impeller, single cycle, single shaft engine with pipe diffuser. Incorporation of a free turbine and a regenerator are viewed as output and cycle options, respectively.

Expectations based on UARL preliminary calculations indicate that the advanced turbine will be competitive in manufacturing cost, fuel economy, and performance, with the conventional engines. It will also offer significant advantages with respect to HC and CO emissions as well as decreased size and weight.

2. Ir. R. A. J. O. van Witterveen, Stirling Group, N. V. Philips, Eindhoven, the Netherlands, discussed the present and projected state of technology for Stirling cycle engines. He noted that Philips' experience with Stirling engines over the past 10 years is based on about 50 engines of seven different types from fractional h.p.'s to 300 h.p. Running hours range from 10,000 for engines to 1 million for component testing. Emissions measurement carried out in the absence of wall quenching and local hot spots within the external burner, together with efficient fuel-air mixing indicate that HC, CO and NO_x emissions will be well below the U. S. 1975-1976 standards. (Suppressed flame temperature burners limiting flame temperatures to about 1500°C are expected to appreciably reduce NO_x levels.) The use of heat pipes further helps to optimize the Stirling cycle for specific output. A 200 h.p. Stirling cycle engine with rhombic drive will be installed in a DAF bus within the next few months. Also, a 100 h.p. Stirling cycle swash plate engine is presently being developed on a test bed for installation in a passenger car body before 1975.

3. Dr. Dean T. Morgan, Thermo Electron Corporation, Waltham, Massachusetts, U. S., presented an account of the work being done on a 100 shaft h.p. Rankine cycle engine with organic-based fluid and reciprocating expander. The use of a trichlorethanol-water working fluid has been found to offer distinct advantages over a water (steam) system. Areas that have been investigated and optimized include expander systems, inlet valving, bearings and feedpumps, boiler-burner characteristics, condenser design and construction, including minimization of required fan power, regenerators, controls, transmission, and engine packaging in an automobile chassis. Rankine cycle engine emissions levels were found to be substantially below those prescribed by the U. S. statutory standards. Dr. Morgan stated that the system design and development is sufficiently advanced to ensure a high probability of meeting the goals and performance estimates presented in his report to the Conference.

4. Mr. Lars T. Ortegren, Project Manager, K. B. United Stirling, Sweden, A. B. and Company, noted that the main objective of his organization was the development and adaptation for production of Stirling cycle engines. A 200 h.p. engine is being developed, allowing exchange with most existing Diesel engines for application to city buses, mining vehicles, boats, and stationary installations. Extensive use is being made of the value analysis technique to minimize outer dimensions and manufacturing costs. Deliveries are planned for 1976, preceeded by earlier pilot production. A two-phase program is being planned, culminating in the installation of a prototype engine in a city bus by 1973. Production models of city buses with exceptionally low exhaust emissions and noise levels is subsequently anticipated.

5. Mr. R. D. Burchard, Regierungdirektor, Economics Ministry, FRG, related that a Special Committee of the Cabinet for the Environment has been established in Germany and that working groups are currently studying various aspects of environmental protection. These include the important area of motor vehicle air pollution. For example, government R&D has already focused on the reduction of lead additives in gasoline. Mr. Burchard recommended the further development of advanced automotive power systems, and in this context mentioned that German firms are doing work on gas turbines and battery systems.

6. Dipl. Ing. K. H. Newmann, Research Development Group, Volkswagen, FRG, reported on the mathematical modeling of NO_x production in a conventional engine. It has been found that predictions of the model agree with lean mixture operation in a single cylinder engine. Also, the formation of some NO_x has been found to occur as a result of chemical reactions in post-flame regions of the combustion chamber at temperatures of 2600°K. Herr Newmann indicated that although Volkswagen is currently experiencing driveability problems with lean mixture engine operation, the company is working toward the accomplishment of a mass production, low emissions, low cost vehicle for 1975.

7. Mr. Diamuid Downs, Managing Director, Ricardo Consulting Engineers, U. K., presented a paper entitled, "A European Contribution to Lower Vehicle Exhaust Emissions" in which he stressed that NO_x emissions requirements will be the most difficult to meet. Mr. Downs confined his remarks to the problems of small European automobiles in meeting future U. S. legislative standards and to the contribution which combustion chamber design can make to reducing exhaust emissions from the Diesel engine. Up to now, the Clean Air Package approach to emissions control has been employed in Europe. Further refinements including petrol injection and possibly manifold air oxidation may be necessary to meet more stringent requirements. Mr. Downs suggested that a double catalytic system for reducing NO_x, HC and CO offers the best chance for European cars to meet U. S. future emissions standards. However, he emphasized that the performance of these systems with respect to durability has not yet been fully assessed. In the case of the Diesel engine, the swirl chamber system has been demonstrated to be effective in lowering gaseous exhaust emissions, particularly NO_x. In view of their possible effects on engine durability, EGR and water injection are not attractive solutions to the further required lowering of NO_x levels; moreover, catalytic reduction of NO_x does not appear to be feasible in the oxidizing atmosphere of Diesel engine exhaust. In this context, Mr. Downs posed the question, "Are we sure that such low levels of NO_x must be achieved in motor vehicle exhaust gases?"

8. Mr. W. A. Compton, Assistant Director of Research, Solar Division of International Harvester, San Diego, California, contributed a paper demonstrating how an optimized Rankine cycle engine combustor and control system produces exhaust emissions well below U. S. 1975-1976 standards. Employing a novel fuel atomization, rotating cup technique

in conjunction with precise control of air-fuel ratio, Solar has developed a burner system which emphasizes low emissions, compactness, fast response, low cost potential and high efficiency. Package size and power requirements of the combustor are not excessive, the fuel is not critical and the components which involve proven concepts are not complex. The system is thus capable of low cost mass production as well as high reliability and efficiency.

Morning Session, February 25 (Continuation of Technical Presentations)

1. A report on a Hybrid Engine - Electric Systems Study was presented by Dr. Joseph Meltzer, Director of Pollution and Resources Programs, Aerospace Corporation, El Segundo, California. The hybrid concept employs two separate power sources for motor vehicle propulsion. One of these is a small heat engine running at approximately constant speed while the other is a battery supply which provides power for transient operation. The requirements for engine acceleration and deceleration are essentially eliminated, leading to a reduction, both in exhaust emissions and in the design requirements for a catalytic converter. The Aerospace study notes that significant improvements in motors and control technology are now readily achievable, and that lead-acid batteries are available which are capable of satisfying hybrid power density requirements. However, improvements in charge, acceptance characteristics, and cycle life are urgently needed.

It is concluded that the hybrid concept which is suited to a variety of heat engines offers the potential for meeting future U. S. automobile emissions requirements.

2. Mr. Bohers, Electrical Section, Citroen, presented a two-part study on electric vehicle technology carried out in collaboration with la Compagnie Francaise de Raffinage and Battelle Institute, Geneva. The first part dealt with the development of a hydrocarbon-air fuel cell operating in the temperature range 800 to 1000°C, avoiding the use of expensive platinum catalysts. A computer model of this battery system was formulated which optimized the effects of a number of parameters, including the dimensions of the cell, the activation polarization, the partial pressure of oxygen at the cathode, the heat liberated, and the minimum and the maximum temperatures of the electrolyte. The second part of Mr. Boher's talk was concerned with an electric drive system employing a three-phase synchronous motor operating from a direct current source.

It was emphasized that the adaptation of a synchronous motor to an electric drive system powered by a fuel cell requires specially designed pulse circuitry employing sinusoidal or rectangular pulse modulation techniques. Mr. Bohers subsequently described these techniques in detail.

3. Research and development on a lithium-sulfur battery operating at a temperature of 375°C and capable of producing 220 watt-hr./kg. was described by Dr. Elton J. Cairns, Section Head, Energy Conversion Section, Argonne National Laboratories, Argonne, Illinois. Emphasis is currently being placed on the removal of Li_2S from the reaction site without losing material to the surroundings, improvement of the capacity density of the cathode current collector and lengthening of the cycle life. Studies are also being made of phase equilibria, interfacial phenomena, suitable cathode materials, solid electrolytes and materials of construction. Computer calculations for an electric vehicle capable of meeting APCO requirements indicate that there is a need for improvement in the capacity density of the laboratory cells and/or the design of the battery. The results demonstrate that electric vehicles based on lithium-sulfur batteries can have ranges of 150-250 km., if 25% of the curb weight is allocated to the battery supply.

4. Mr. Shizume, Japanese Automotive Manufacturers' Association (JAMA), Japan, described a research and development plan designed to produce an electric car for urban areas during the period 1971 to 1975. Five different size vehicles will be developed in addition to a bus, at a total estimated cost of thirteen million dollars. The R&D capacities both of national organizations and the private sector will be concentrated on this project to reduce vehicle exhaust gas emissions and engine noise. Component development work will be done on lead-acid batteries, new type batteries, motors and controls, plastic bodies, etc. Specifications for the experimental medium scale passenger car are: total weight - 2000 kg.; maximum speed - 80 km/hr.; acceleration - 0-30 km/hr. in 3 seconds; and range 180-200 km. Mr. Shizume also outlined the National Research and Development program (the Ogata project) which is managed by the Agency of Industrial Science and Technology assisted by advisory and evaluation committees. The program supports selected projects proposed by government organizations, national laboratories or private companies on the basis of importance, degree of need, possible spin-offs, and financial requirements and risks.

5. Mr. G. Brusaglino, Chief, Electrical Research Department, Fiat Research and Development, discussed his company's experience with electric drive systems for small automobiles which dates back to 1961. In view of recent advances in electric drive technology, Fiat is currently performing in-depth studies on electric vehicles. For urban operation, agility in traffic based on rapid acceleration, regenerative braking, continuous speed control and economical maintenance are essential. Specifications were given for Fiat Models 850 and 500 converted to electric drive, each utilizing a Fiat six pole, compound excitation motor. These vehicles have the capability of being upgraded for non-urban applications. Mr. Brusaglino also mentioned that Fiat is collaborating with Philips (Milan) on an electric drive system for a bus. In addition, Fiat is considering the design and construction of a hybrid bus employing a gas turbine as the heat engine.

6. The final technical paper of the meeting was presented by Mr. J. Beslier, Centre d'etudes Peugeot, La Garenne-Colombes, France, who discussed the fuel cell as a source of electric vehicle propulsion. Mr. Beslier discussed a number of diverse aspects of electric car technology as seen by Peugeot such as the size of the vehicle, chassis strength and survival space, preferred designs for mass-produced motors and generators, regenerative braking, and power sources. He stated that the performance of electric vehicles will be limited by the types of batteries available which should be capable of supplying a specific energy in the range of 450 watt-hrs./kg. He concluded that the use of fuel cells provided the only long-term solution to the power requirements of the electrically driven vehicle. At present, Peugeot and la Societe Alsthom, France, are cooperating on the development of a fuel-cell for this purpose.

7. Mr. M. Ceylan, Istanbul Technical University and member of the Turkish Scientific Corporation, made a few brief remarks related to motor vehicle air pollution in Ankara and the existing need for control measures there.

8. Dr. John H. Ludwig, Chairman, summarized the proceedings of the Conference and expressed his appreciation to the delegates for their participation. He restated the basic proposal being offered by the U. S. which would extend the goals of CCMS to include cooperative programs on low emissions, advanced automotive power systems. He noted that although the time scale for reducing motor vehicle emissions in Europe differs from that in the U. S., such cooperation would be beneficial to all concerned.

9. Additional closing remarks were made by Ir. J. G. Kuiperbak, Ministry of Transport, the Netherlands, who thanked the delegates for their attendance at the Conference and for their contributions to the attainment of clean air.

10. A press conference lasting about one hour was held immediately after the meeting.

11. The afternoon was given over to a tour of the Stirling Engines Product Group facilities in Eindhoven followed by one final meeting at N. V. Philips for refreshments and farewells.

Appendix A

Presentation

by

H. J. de Koster, State Secretary
Foreign Ministry, The Netherlands

Ladies and Gentlemen--It gives me great pleasure to welcome you here on behalf of the Netherlands Government. You have come to Eindhoven by air, by rail and by car to discuss the development of "clean" motor car engines. I feel quite guilty by having arrived by car all the way. First of all, I should like to thank the American Government for having taken the initiative by urging that a conference be held on the subject; I should also like to thank the two Dutch firms, Philips and DAF, that are helping us so effectively with the organization.

When the United States Government announced a few months ago that the development of low pollution power systems would be considered within the framework of the CCMS Air Pollution Project, Holland's interest was immediately aroused and not without reason. The Netherlands is the most densely populated country in the world and the "car density" is high and is rapidly increasing; consequently, the pollution of the atmosphere with exhaust gases is becoming a major problem that we simply must tackle and for that reason the Netherlands Government is pleased that the first international conference on the development of new power systems for motor vehicles is being held in this country.

The struggle against air pollution is not new. Hundreds of years ago people tried to lessen the smoke emitted by stoves and furnaces. Nor is there anything new in our quest for a vehicle that does not pollute the atmosphere; at all events, that is what we might conclude when we read of the experiments conducted as far back as the 17th century by the Dutchman Simon Stevin, who endeavoured to develop a carriage with sails on country roads, as there were no other roads, a vehicle propelled by clean wind. Although cleaner roads was probably not the main object of Stevin's historic experiment, the development of a "sailing carriage" in those days might very well have helped incidentally to eliminate a certain type of road pollution ascribable to horse traction.

I gather from the program for your conference that in the next few days you will be studying various systems of propulsion, the principles and practical application of which are far more complex than those that were a challenge to Simon Stevin and prompted him to experiment with a "sailing carriage."

Science has opened up a vast new field of technical expedients for traffic and transport since the 17th century and the problems involved have of course also proliferated as the aircraft industry is batting with the problems of noise, but also with the jetstream. The primary endeavour that still runs through all man's activities in this sphere is to construct

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vehicles that satisfy his threefold desire for speedy, cheap and safe locomotion. A fourth and salutary requirement that has become increasingly important in the last few years is that vehicles should impair the purity of the air as little as possible, and next to that make little noise as possible.

The desire for low pollution power systems has of course also been felt in the Netherlands, where the concern that is offering the conference hospitality for three days has been working for many years to perfect the Stirling engine.

I am pleased to see that the Stirling Cycle is one of the systems you are going to investigate. Dutch experts contend that adopting the Stirling engine would help us in no small measure to counter the menace of air pollution which literally hangs over us all. I presume the experts will be giving you a great deal of information on this system, the development of which is receiving the support of the Netherlands Government.

You do not expect me, I hope, to say anything in my welcoming speech nor in any other speech that will help to increase your knowledge of engine systems or engineering techniques. What I do wish to do is draw your attention to the fact that your activities, which are now very largely of a technical nature, may have far reaching political and economic repercussions.

The outcome of your efforts will settle the future of the motor car, the symbol of our mobility, our freedom as individuals and our prosperity. If I am not mistaken, we shall only be able to continue to tolerate the motor car in our midst if we can develop a suitable power unit, one that will only pollute the atmosphere very slightly, if at all, and will at the same time be economically within reach of the public at large.

A most important aspect of the matter is that you are about to launch a new form of international cooperation in this sphere. I should like to stress, also here, that international cooperation on a broad basis is absolutely essential, because the international trade in motor vehicle can only continue to grow uninterruptedly if the nations cooperate. Untrammelled trade and the concomitant international competition will provide the essential incentive to produce motor vehicles that are both "clean" and reasonably cheap.

In view of this, I believe we should do all we can to prevent countries from adopting widely divergent requirements which newly manufactured or imported motor vehicles must satisfy; uniformity would be in the interest of every country in the world.

Whatever we do, we should prevent our necessary concern for the environment from being used to erect unnecessary trade barriers.

For this reason I am glad that the CCMS resolved some time ago to institute a pilot system. To speak in nautical terms, we shall need a highly skilled pilot to steer a safe course between the Scylla of air pollution and the Charybdis of potential obstacles to trade.

Nevertheless, I hope, indeed I am confident, that our American friends who are acting as "pilots" in the CCMS project will search both energetically and patiently until they find a course suitable for all countries desirous of seeing road transport develop in an environment in which breathing is a health-giving occupation. In order that I may come by car on a next conference here with a clean motor and a clear conscience realizing also that the unlimited use of the motor car is not based on the size of the roads or the parking space but also on the success of this conference.

After having achieved your goal the next conference will have to concentrate on the collapsible motor car, which you can put into the kitchen or behind the closet during the night. In between we will be interested in the "car without accidents," the one which stops automatically when danger is ahead, the car which refuses to be started when somebody who has been drinking liquor gets behind the wheel.

Appendix B

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Closing Remarks of the Meeting

by

John H. Ludwig, Chairman
NATO/CCMS Conference on Low
Pollution Power Systems Development
Eindhoven, Netherlands

Fellow Delegates--As the representative of the U. S. delegation and the chairman of this NATO/CCMS Conference on Low Pollution Power Systems, I, of course, can only summarize and draw conclusions based on my particular point of view and the purposes that we had in mind as we approached this meeting several days ago and watched it progress during the last three days.

So let me share with you my reactions to this Conference.

First and foremost I hope--and I do believe that we have succeeded--that we have been able to bring to you a clearer understanding of both the rationale and the approaches that guide the approach to cleaning up motor vehicle pollution in the U. S. Although we understand, to some degree at least, the problems posed to European nations by the severe emissions control limitations imposed on 1975-76 motor vehicles in the U. S., I hope we have been able to bring to you a better understanding of this problem in terms of the determination of the American people through our Congress to eliminate the motor vehicle as a significant source of air pollution.

And, in addition--and this may be just a surmise on my part--this concern of ours in American has perhaps been instrumental in alerting some of you at least to the full scale of promise--good and bad--that comes with the concentration of more motor vehicles in confined urban areas. If so, then this, in my opinion, is all to the good.

But to get back to the basic proposal incorporated in extending the CCMS Air Pollution Project to include the examination of interest for cooperative programs dealing with Low Pollution Power Systems Development. Now that each of us has a better understanding of each other's programs and interests than we had before we commenced the Conference on Tuesday--and I can assure you that my understanding of your interests and programs has been greatly increased by our "crowded" meetings with their overflowing agenda--it behooves all of us to give serious consideration as to how we may join forces in seeking solutions jointly in those areas where we have an active and demanding interest. We, in particular, will examine our program needs once again in depth with respect to what we have learned here.

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And for each of you, I hope you will give serious consideration in cooperating in either of our two programs--our Advanced Automotive Power Systems Program, or our Federal Clean Car Incentive Program. We are flexible in our consideration of programs to fit the peculiar needs of both cooperators, for it is our experience that the will to cooperate is the prime requisite for successful cooperation and, if this exists, then the route to cooperation can in most cases be found.

As indicated earlier during our presentation, our desire to cooperate extends to either governments or private companies participating in this Conference. And we continue to solicit your active participation in our competitive programs dealing with this problem. I, for one, believe that such cooperation will be mutually beneficial, albeit the time scale of the need may not be quite as urgent for you here in Europe as it is for us in America. So we will continue to be alert to your desires to pursue discussions as to possible cooperation.

Before I close, I would be remiss if I did not, on behalf of all of us attending this meeting, applaud in no uncertain terms the fine hospitality that has been our priviledge to enjoy in Eindhoven.

- to the Government of the Netherlands for their concern and interest in our program, and for their kindnesses, both professional and personal.

- to the Mayor of Eindhoven for his fine hospitality provided in his admirable Town Hall.

- to the Philips Company for providing our meeting facilities and the many services attendant thereto, and their attention to our personal needs.

- to the DAF, for their perserverence in adjusting their schedules to fit our needs and, in addition, for their attention to our personal welfare.

- and to the CCMS, for their support to the program which made it possible for us to be here this week in the first place.

And on behalf of the U.S. delegation, I would like to thank you, the participants, for many things:

- for bearing with me under the time constraints of too many papers in two little time;

- for your cooperation and forgiveness for any shortcomings in my efforts to serve you;

- and last, but not least, for your active participation, for without that, we would have realized little success at all.

In closing, then, again, my thanks to each and every one of you.

Appendix C

PARTICIPANTS, CCMS CONFERENCE

U.S.A.

Government

Dr. John H. Ludwig	Assistant Commissioner for Science and Technology, Air Pollution Control Office (APCO), Environmental Protection Agency
Dr. Kay H. Jones	Director, CCMS Air Pollution Pilot Study
Dr. Louis J. Schoen	Executive Secretary, Advisory Committee on Advanced Automotive Power Systems, APCO
Dr. Ronald Engel	Assistant Director, Bureau of Criteria and Standards, APCO
Mr. John Brogan	Director, Division of Motor Vehicle Research and Development, APCO
Dr. Tom Winter	Staff Member, Council on Environmental Quality
Mr. Donald A. Kruse	U.S. Mission to NATO
Mr. S. H. Burnett	Deputy P.A.O. at U.S. Mission, NATO
Mr. Leopold Gotzlinger	Trade Promotion Officer, U.S. Consulate General, Rotterdam
Mr. L. Demmers	Public Affairs, U.S. Embassy, The Hague
Mr. Arthur Breisky	Second Secretary

Industry

Mr. Edward S. Wright	Chief, Ground Systems Analysis, United Aircraft Research Laboratories
Mr. Joseph Meltzer	Director of Pollution and Resources Program, Coordination Planning, Aerospace Corporation
Dr. Dean T. Morgan	Special Products Staff, Thermo Electron Corporation
Mr. William Compton	Assistant Director - Research, Solar Division, International Harvester Co.
Dr. Elton J. Cairns	Section Head, Energy Conversion Section, Chemical Engineering Division, Argonne National Laboratories

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THE NETHERLANDS

Government

His Excellency H.J. deKoster	State Secretary, Foreign Ministry
His Excellency M.F. Vigeveno	H.M. Roving Ambassador
Miss Drs. J. Buzeman	Foreign Ministry
Mr. W.J. Elzinga	Foreign Ministry
Mr. B.W. Quist	Ministry of Transport
Ir. J.G. Kuiperbak	Ministry of Transport
Dr. W. Horn	Ministry of Transport
Dr. J. Spaander	Ministry of Social Affairs and Public Health
Drs. F. Hartogensis	Ministry of Social Affairs and Public Health
Mr. F.J.J. Besier	Ministry of Social Affairs and Public Health
Mr. W. Vlaardingerbroek	Ministry of Social Affairs and Public Health
Drs. R. van Kuik	Ministry of Economic Affairs
Drs. W. Visser	Ministry of Economic Affairs
Mr. C.J. Schneider	Netherlands Mission to NATO
Drs. P. Winkel	TNO (Central Organization for Applied Scientific Research)
Ir. P.D. van der Koogh	TNO
Mr. J. van der Weyden	TNO
Drs. P. Scheltus	TNO
Dr. R. Guicherit	TNO

Industry

Mr. W.Th.N.M. Hustinx	RAI
Dr. S. Herzberg	Royal Dutch Shell
Ir. G. van Amstel	Director Technical Dept. DAF
Ir. W. Quik	Technical Dept. DAF
Ir. C. Veenemans	Technical Dept. DAF

THE NETHERLANDS

Industry (Cont'd.)

Ir. T. Tjioe	Technical Dept. DAF
Mr. A. Hoynck van Papendrecht	DAF
Mr. A. Schutz	DAF-P.R.
Ir. P.J. Hagendoorn	N.V. Philips - Director, Special Affairs
Dr. Ir. R.J. Meyer	N.V. Philips - Scientific Advisor Research Laboratories
Dr. F.P.K. de Jong	N.V. Philips - Stirling Group
Ir. R.A.J.O. van Witteveen	N.V. Philips - Stirling Group
Ir. H.C.T. van Beukering	N.V. Philips - Stirling Group
Dr. Ir. J.A. Rietdijk	N.V. Philips - Stirling Group
Dr. Ir. T. van der Ros	N.V. Philips - Stirling Group
Ir. R. van Giessel	N.V. Philips - Stirling Group
Ir. H.A. Jaspers	N.V. Philips - Stirling Group
Dr. Ir. G.T.M. Neelen	N.V. Philips - Stirling Group
Mr. L. Loeffler	N.V. Philips - Stirling Group
Ir. A.P.J. Michels	N.V. Philips - Stirling Group
Mr. H.L. van der Tuuk	N.V. Philips - P.R.
Mr. G.W. Hardeman	N.V. Philips - P.R.
Ing. A. Seiffert	Aral N.V.
Mr. W.C. Hopper	Stichting Motorproeven
Ir. H.F. de Jonge	Kon. Instituut van Ingenieurs V 2 sectie Automobieltechniek
Ir. J.K.P. Sloos	Product Engineer in charge of automotive control and engine emissions - Esso

NATO

Mr. G. Randers	Deputy Secretary General, CCMS
Mr. L. Thiebault	CCMS Secretary
Mr. A. de Vries	Information Officer

OECD

Mr. K. Orski	Chief, Transportation Research Environment Directorate

EUROPEAN COMMISSION

Mr. P. Schlosser	Director responsible for technical standard

BELGIUM

Government

Mr. Verduin	Ministry of Public Health
Mr. Verlinden	Ministry of Communications

CANADA

Industry

Mr. W.A. Woodcock	General Motors of Canada

DENMARK

Government

Mr. N.E. Nielsen	Automobile Inspection Board

FRANCE

Government

Mr. Frybourg

Mr. Osselet

Mr. Bonnemay

Mr. Fayard

FRANCE

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Mr. Martin	Chambre Syndicale des Constructeurs d'Automobile
Mr. Chapoux	Union Technique de l'Automobile et du Cycle
Mr. Bois	Berliet
Mr. Linard	Chrysler France
Mr. d'Herdigny	Chrysler France
Mr. Clavel	Citroen
Mr. Bohers	Citroen
Mr. Desblades	Citroen
Mr. Ducrot	Citroen
Mr. Chopin	Peugeot
Mr. Beslier	Peugeot
Mr. Vuaillat	Renault/Saviem
Mr. Chenevez	Renault/Saviem

GERMANY

Government

Mr. K.D. Burchard	Regierungsdirektor, Economics Ministry
Mr. H.H. Eggelman	Transport Ministry
Mr. Dreyssgacker	Department of the Interior

Industry

Prof. Kratz	M.A.N.
Dipl. Ing. K.H. Neumann	Volkswagen - Research Development
Dr. K. Binder	Bosch - Stuttgart
Mr. Gewinner	Daimler Benz

GREAT BRITAIN

Government

Mr. J. Furness	Department of Environment
Mr. D. Lyness	Department of Environment
Mr. P. Sherwood	Department of Environment
Cmdr. Tyrell	Department of Trade

Industry

Mr. McEwan	Vauxhall
Mr. Oliver	Ford
Mr. Weaving	Britisch Leyland
Mr. Downs	Ricardo Research
Mr. Campbell	Society of Motor Manufacturers and Traders
Mr. S. Hiscock	Lead Development Association

ITALY

Government

Ing. G. Rossini

Industry

Ing. G. Savonuzzi	Fiat
Ing. G. Torrazza	Fiat
Mr. G. Brusaglino	Fiat

JAPAN

Government

Mr. Suzuki	Ministry of Industry

Industry

Mr. Shizume	Jama
Mr. Kamimura	Toyota

JAPAN

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Mr. Miyajima	Nissam
Mr. Ozawa	Honda

SWEDEN

Industry

Mr. S. Morstedt	AB Atomenergie, Studsvik
Dr. S. Wallman	AB Volvo
Civ. Ing. N. Wallde	AB Scania - Saab, Sodertalje
Mr. L. Ortengren	United Stirling

TURKEY

Industry

Mr. M. Ceylan	Istanbul Technical University